Search for $K_L \rightarrow \pi^0\mu\mu$ in 1999 Data

- Outline
  - Issues from last meeting
    - KL→$\pi^0\mu\mu$ analysis
      - KL→$\pi^+\pi^-\pi^0$ MC:decay & punch-through - MC/Data mismatch
      - Implementing KL→$\pi^+\pi^-\pi^0$ MC changes
        - Magnet simulation
        - KL→$\pi^+\pi^-\pi^0$:No forcing of decay or punch through – Select decay/punch-thru events at generator level
      - New issues with KL→$\pi^+\pi^-\pi^0$ MC - No selection at generator level
  - Plans

Old KL→$\pi^+\pi^-\pi^0$ MC

- Generated KL→$\pi^+\pi^-\pi^0$ MC
  - Forced both πs to decay
  - Forced both πs to punch through
- Normalizations
  - Pion forced decays
    - Force pions to decay between 90m-188m
    - Probability is based on lifetime and pion momentum
  - Pion punch-through *
    - Use punch through probability from Masayoshi's GEANT study
  - Need event weight for correct distributions (Evt wt = Pπ+ * Pπ-)
    - Normalization issue from previous analyses

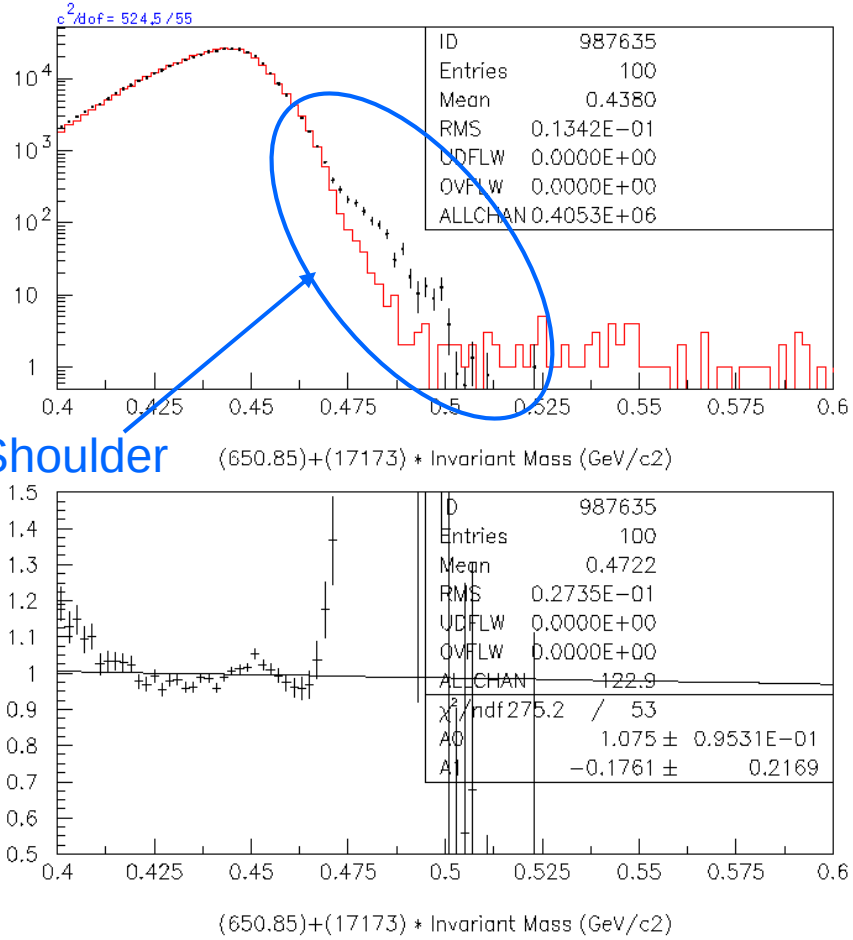
* Problem – punch through probability was for pions that MIP in CsI. My program applied this probability to ALL pions

[Not a big issue since I floated the relative distributions anyway]

1999 Data/$K_L \rightarrow \pi^+\pi^-\pi^0$ MC Comparison

- $K_L \rightarrow \pi^+\pi^-\pi^0$ MC
  - Normalizations
    - Forced decays – generated ~1 x 1999 data set
    - Punch through – generated ~35 x 1999 data set? (Wrong: applied MIP punch through prob to all pions)
    - 1 decay + 1 punch – same normalization problem as above
  - Data/MC scalings are from fit
    - Need to check normalizations to see if scalings from fit make sense (Decide to generate not forcing the decays (no event weight needed))

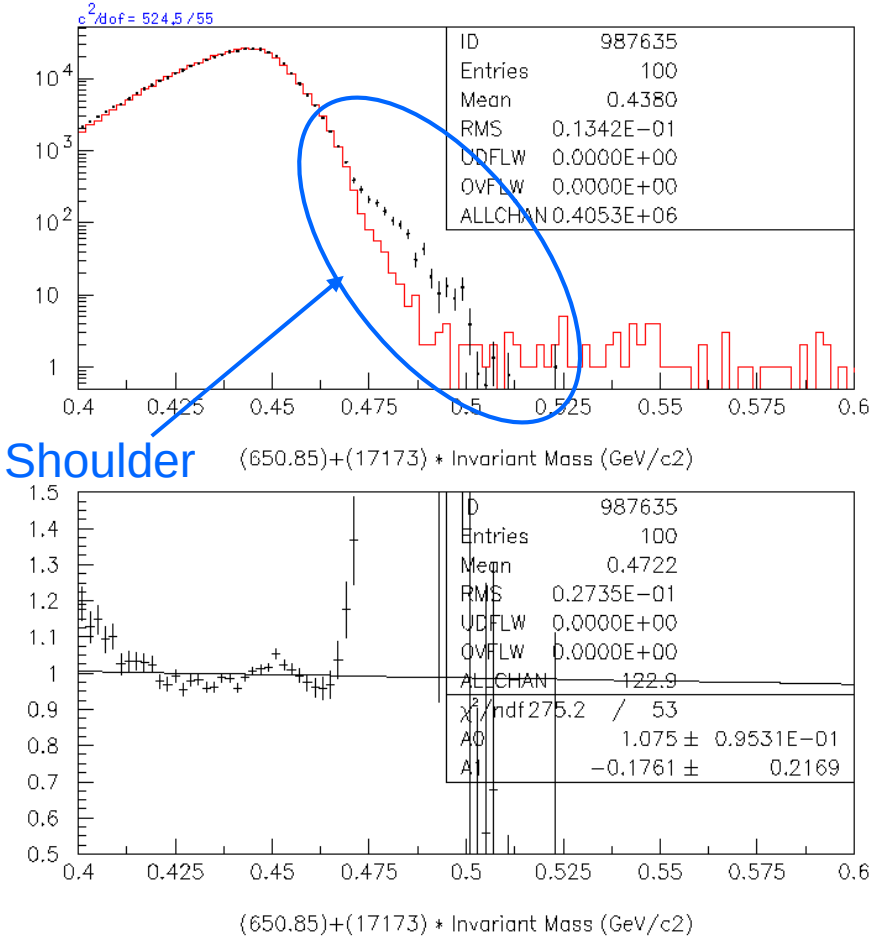
$K_L \rightarrow \pi^0\mu\mu$ Invariant Mass



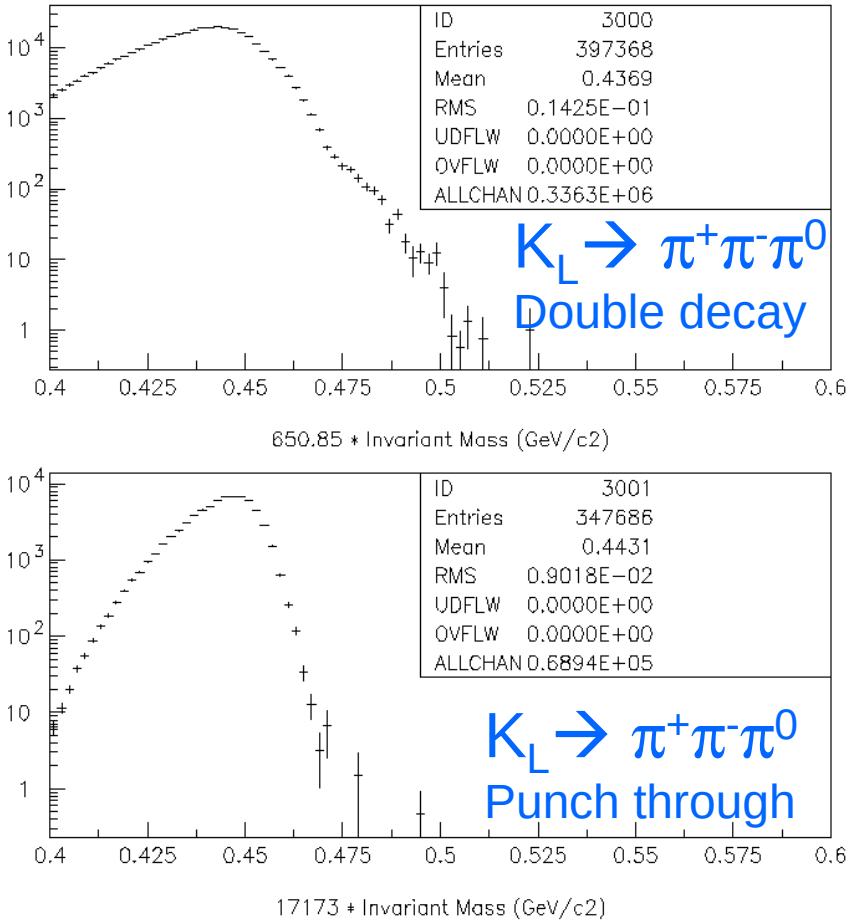
Before cuts around $M_{3\pi}$ and Pt^2 cut

Invariant Mass Contributions

Invariant Mass: Data/MC



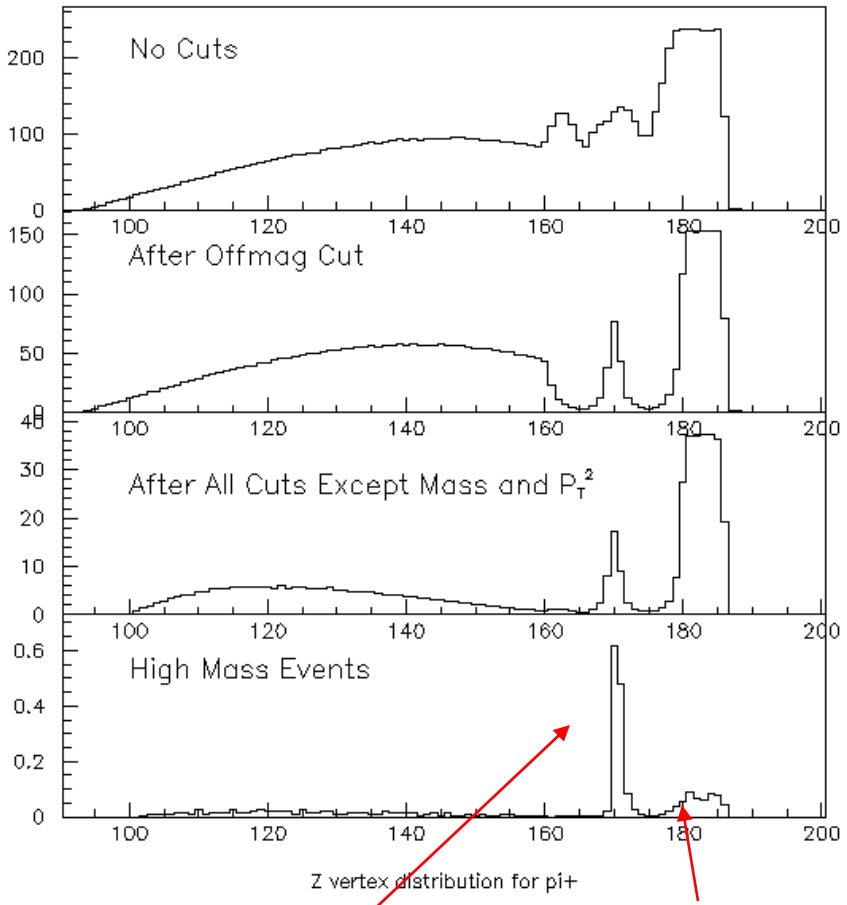
Invariant Mass: $K_L \rightarrow \pi^+\pi^-\pi^0$ MC



High Mass Events

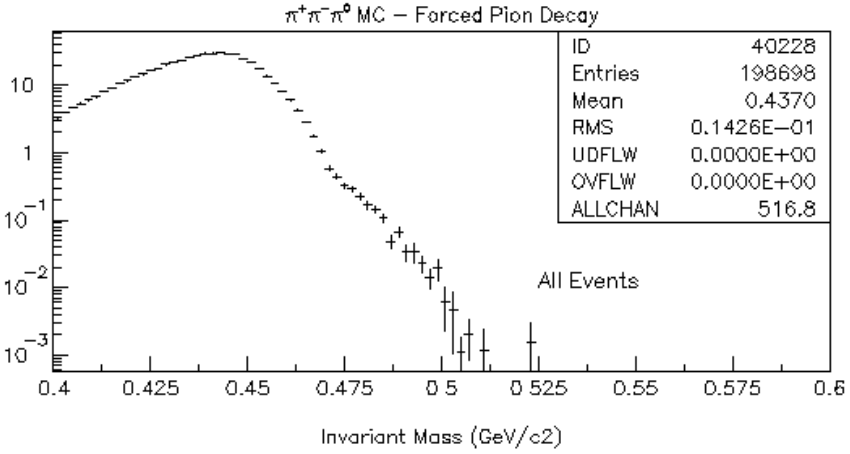
- Trying to understand the high mass events
  - Pion decay vertex distribution of events
    - As expected offmag cut removes all but pion decays in magnet and decays downstream of DC4
    - High mass events seem to come predominantly from the magnet region

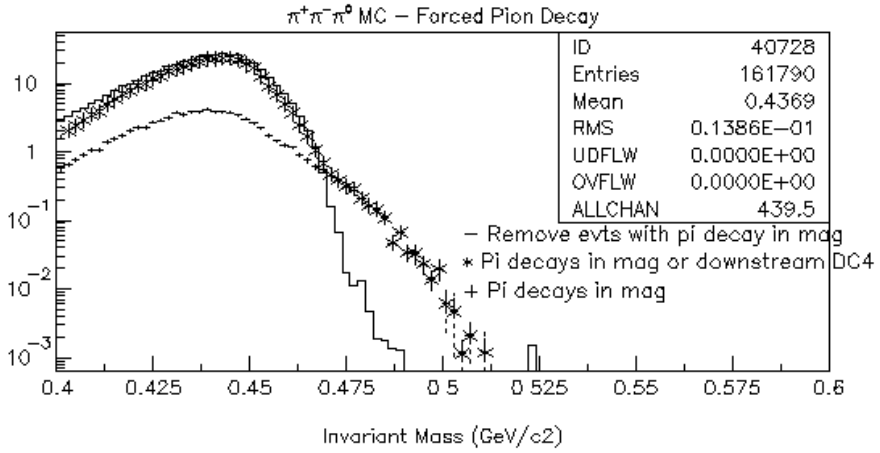
Z vertex of π+ decay

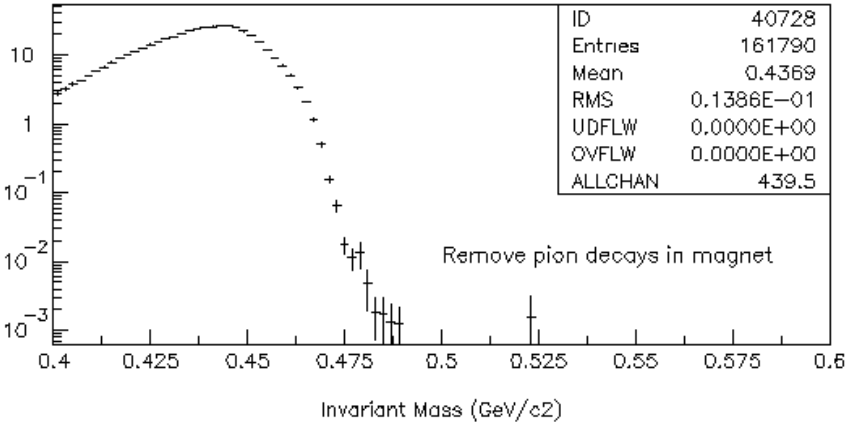


Separate High Mass Events

- High mass tail comes from pion decays in the magnet

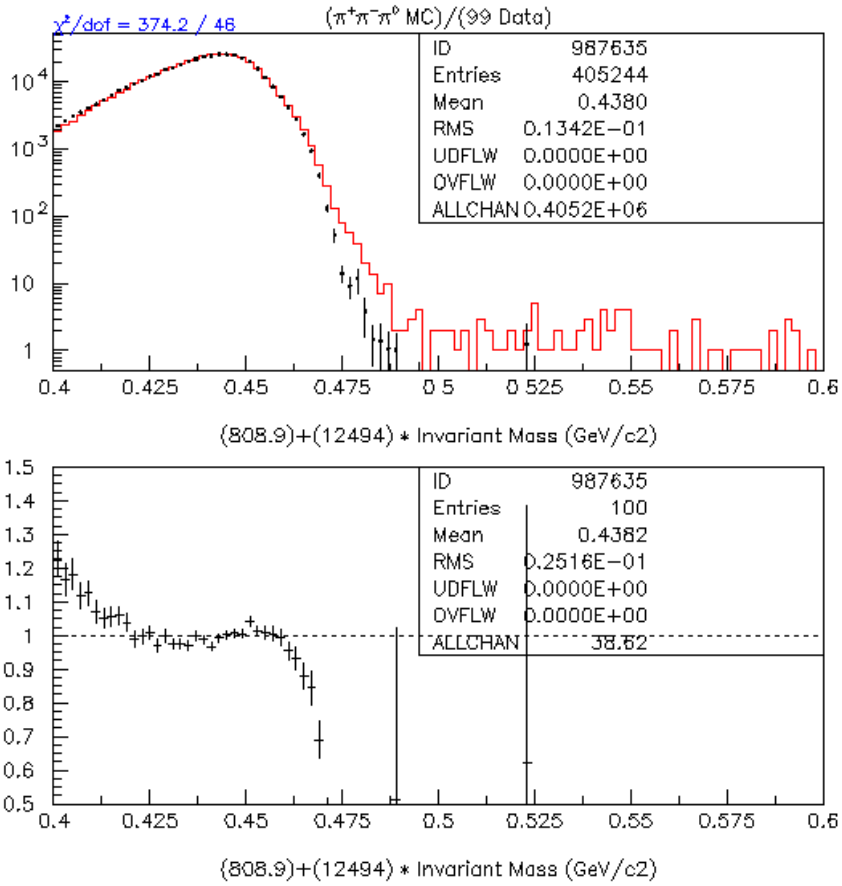






Data/(MC-decays in magnet)

- Fit to data removing events with pion decays in magnet
  - Better fit, but now the MC underestimates the higher mass region
- Tony suggests the problem is the simulation of the magnet kick
  - Same problem seen by analyses looking at electrons that radiate in the magnet
  - Use Mike Wilking's program to swim the events through the magnet



Changes to KL→$\pi^+\pi^-\pi^0$ MC

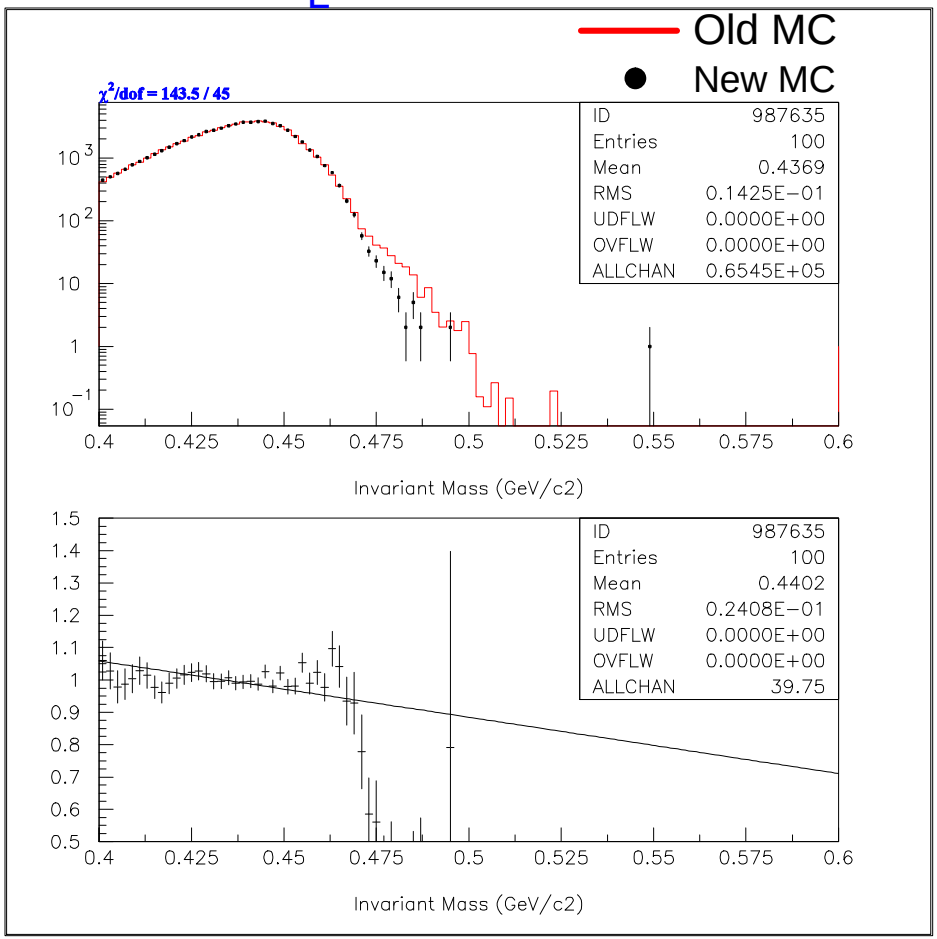
- Implement the following changes to my v6.00 MC
  - ✓ Use Mike Wilking's magnet swim routines
  - Don't generate punch through and pion decays separately
    - Run using ktevmc, selecting events with 2 pion decays, 2 punch throughs or 1 punch + 1 decay
    - Use RickK's v.6.02 pion punch through routine
      - Uses probabilities determined from Vus data ($P_{MU3\ punch}$~6.6E-5*Eπ)
    - Problem: Rick's program generates punch through at Stage 35 (after digitization)
      - Only generates punch through for pions that MIP in CsI (33%)
      - All $\pi^+\pi^-\pi^0$ events must go through digitization

      → SLOW
    - ✓ Fix: Generate punch through at Stage 20 (after tracing)
      - Modify punch through probability to apply to ALL pions
      - Remove punch through events that don't MIP at Stage 35

Old /New $K_L \rightarrow \pi^+\pi^-\pi^0$ MC Comparison

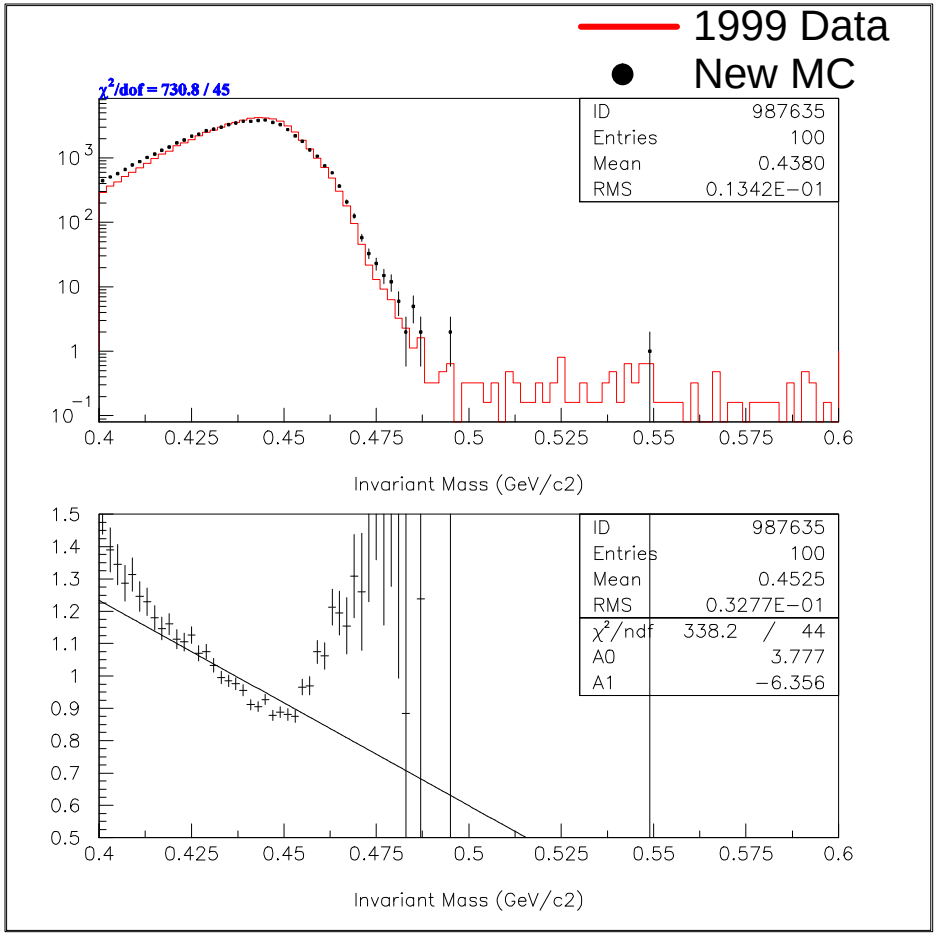
- Compare old $K_L \rightarrow \pi^+\pi^-\pi^0$ MC versus new $K_L \rightarrow \pi^+\pi^-\pi^0$ MC where I've selected events with 2 pion decays, 2 punch throughs or 1 punch + 1 decay

$K_L \rightarrow \pi^+\pi^-\pi^0$ MC



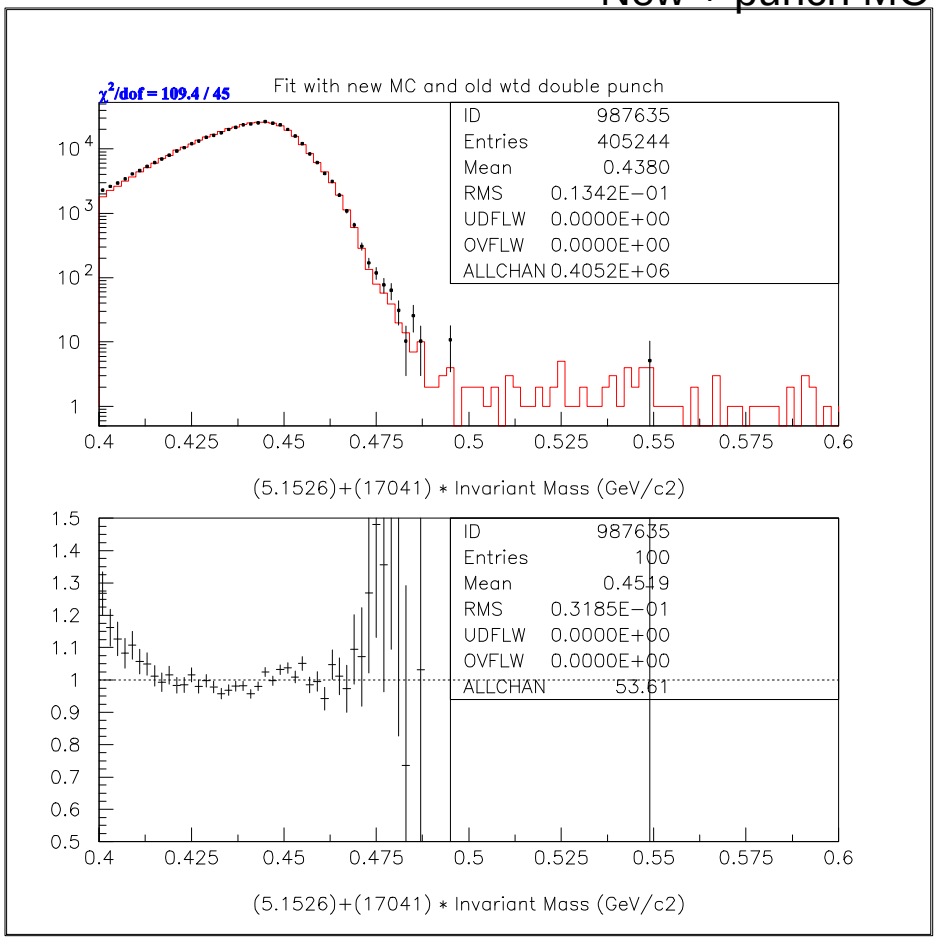
1999 Data/New $K_L \rightarrow \pi^+\pi^-\pi^0$ MC

- Fit 1999 Data with New $K_L \rightarrow \pi^+\pi^-\pi^0$ MC, where I've selected events with 2 pion decays, 2 punch throughs or 1 punch + 1 decay
  - Floated MC in fit (normalization doesn't seem correct)
  - Shoulder is gone, but shape is still wrong



New + old punch-thru $K_L \rightarrow \pi^+\pi^-\pi^0$ MC

- Fit 1999 data using new MC and old punch-through MC (wtd evts)
  - Fit is better, but new MC already has punch-through!
  - Absolute normalization still doesn't quite make sense
    - Underestimated punch through?
    - Something else is missing?
- Real problem is that I'm missing other classes of events!



$K_L \rightarrow \pi^+\pi^-\pi^0$ MC – no selection

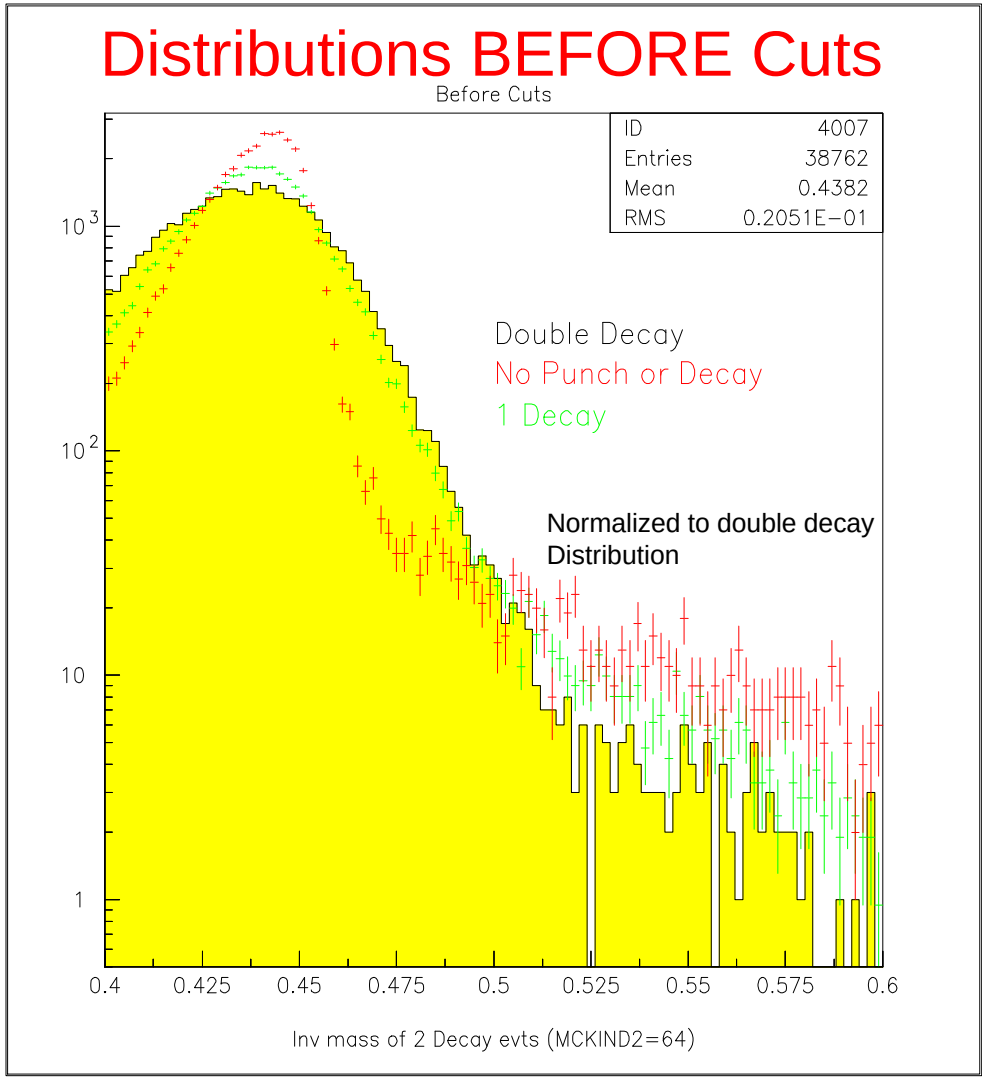
- What about accidental events that fire the muon banks?
  - 6 distinct classes of events
    1. 1 Decay + Accidental
    2. No decay or punch-thru
    3. 1 Punch-thru + Accidental
    4. 1 Decay + 1 Punch-thru
    5. 2 Decays
    6. 2 Punch-thrus
  - Run MC with no selection
    - Let KTEVMC $K_L \rightarrow \pi^+\pi^-\pi^0$ run normally
    - Select Trigger 5 Events ($K_L \rightarrow \pi^0\mu^+\mu^-$, $K_L \rightarrow \mu\mu\gamma\gamma$)
      - 2V * DC12 * 2MU3_LOOSE * PHVBAR1 * 2HCY_LOOSE * HCC_GE2

"Non-selected" $K_L \rightarrow \pi^+\pi^-\pi^0$ MC

	Output of MC	After all cuts except pt2&Mass	After all cuts except Mass
No Decay or Punch	23%	3%	9%
1 Punch	> 1 %	> 1%	> 1%
1 Decay	49%	19%	24%
1 Punch + 1 Decay	> 1%	> 1%	> 1%
2 Decays	28%	77%	68%
2 Punch	0%	0%	0%

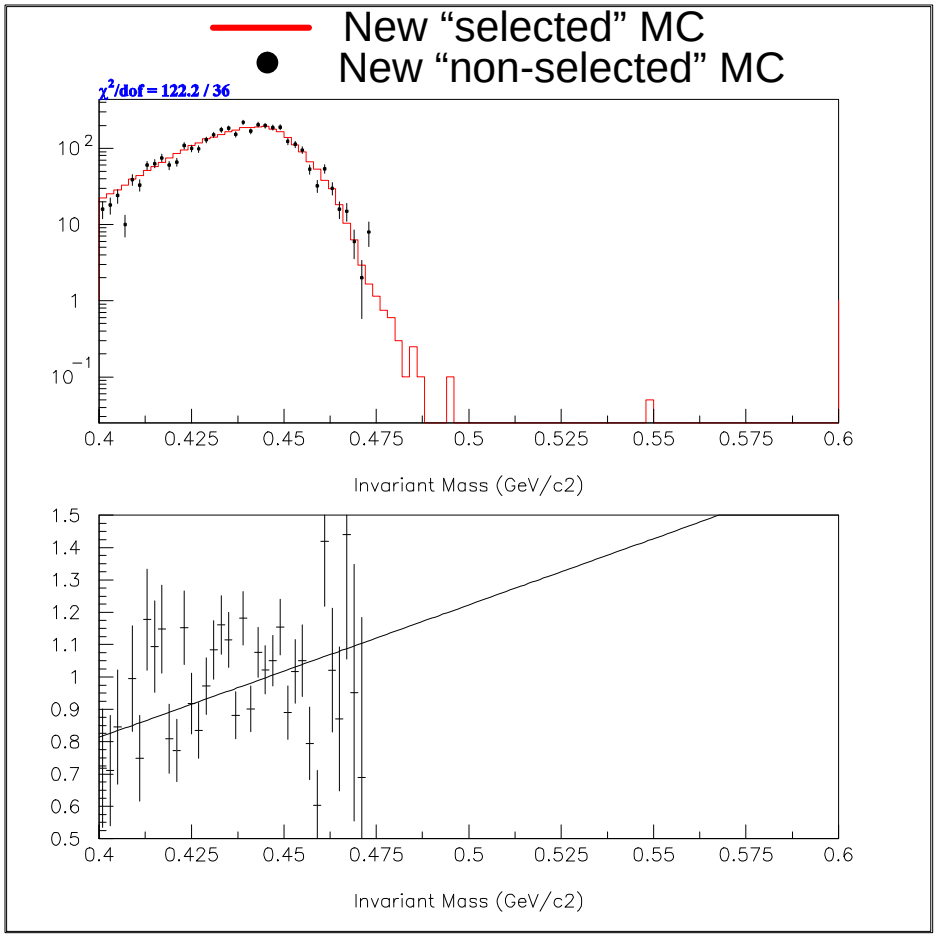
$K_L \rightarrow \pi^+\pi^-\pi^0$ MC Inv Mass Distributions

- New "non-selected" $K_L \rightarrow \pi^+\pi^-\pi^0$ MC has 3 major components after all cuts
  - Double Decay (68% after all cuts)
  - 1 Decay + Accidental (24% after all cuts)
  - No Decay or punch-thru (9% after all cuts)
- Inv Mass distributions for 3 major components are very different
- Need to look at same plots AFTER all cuts
  - Right now I don't have the stats (I've only generated 1% of 1999 data set)

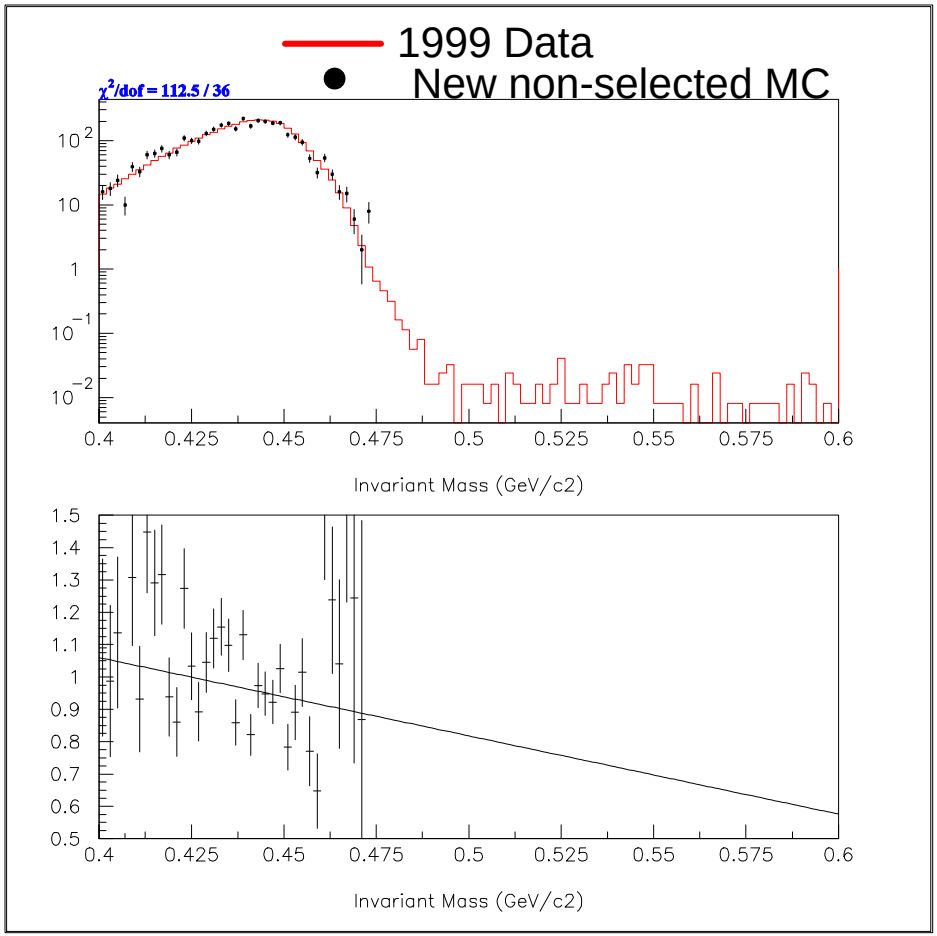


“Non-selected” MC AFTER Cuts

New MC: Selected v Non-selected



Fit non-selected MC to data



Not enough “non-selected” $K_L \rightarrow \pi^+\pi^-\pi^0$ MC

Current Issues

- Normalization is better, but stats on non-selected $K_L \rightarrow \pi^+\pi^-\pi^0$ MC are low.
  - $K_L \rightarrow \pi^+\pi^-\pi^0$ MC (non-selected)
    - I've only generated 1% of 1999 data
- $K_L \rightarrow \pi\mu\nu$ MC
  - I've stripped off accidentals with > 3 GeV in CsI
    - Speeds up generation by ~factor of 5
    - Possible problem: my L2 acceptances with >3GeV acc is 8.5% lower than with standard acc file
  - I've only managed to generate 4% of data
- Farm is needed
  - SashaG has copied over accidental files and set up 799 DB/Libraries
  - I've copied over trigger/FIC files
  - Compile and tested ktevmc code. Still working on porting over analysis code

Plans

- Start to generate new MC ($K_L \rightarrow \pi^+\pi^-\pi^0$) on Farm in the next week
  - One 1999 Data set should take ~10 days (if FARM~300 kpasa CPUs)
- Generate MC ($K_L \rightarrow \pi\mu\nu + \gamma$acc)
  - I need to double check that I have enough accidentals
    - Only 1/3 accidentals on disk. Strip off >3 GeV acc from tape?
  - Make sure I'm not biasing my MC with the > 3 GeV in CsI Accidental events
  - One 1999 Data set should take ~8 days to generate w/o stripped accidental files
    - Probably not worth using >3GeV acc, but do I need more accidentals?
- Reduce background near box with additional cuts
  - Neutral v. charged vertex cut?
  - Upstream/downstream track-angle cut?
  - Kinematic fit?